$\pi^{\pm}$ Charge Exchange Cross Section on Liquid Argon[1]

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Outline

Defining Charge Exchange

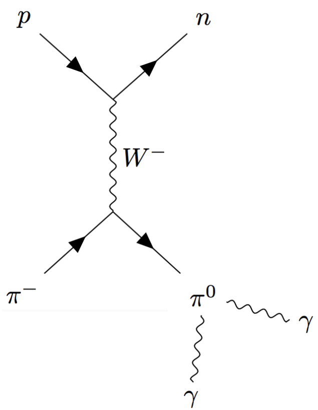


Figure: A CEX interaction must consume the incident pion. Two photons and any number of nucleons may exit

Defining Charge Exchange

Event Images

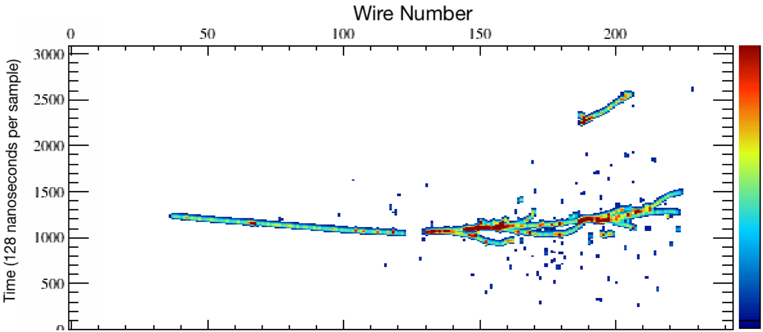
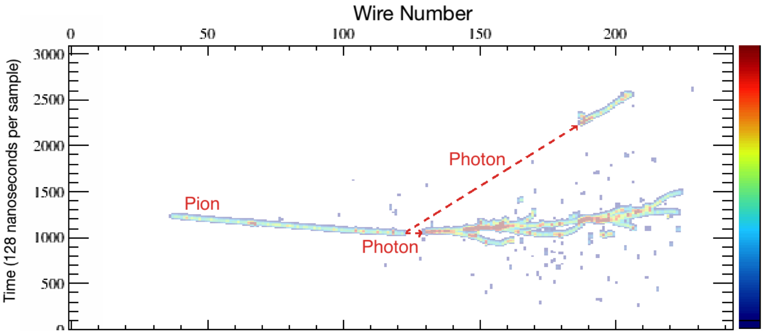


Figure: Event Image for a simulated charge exchange interaction. The photons are electrically neutral and therefore are not directly detectable. No charged pions leave the interaction vertex.

Defining Charge Exchange
Event Images



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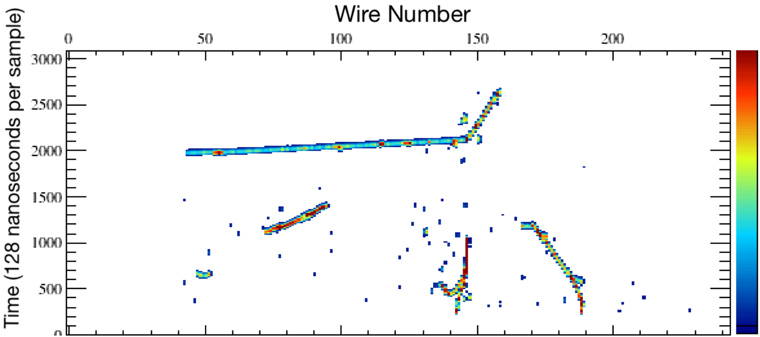

Figure: Event Image for a simulated pion decay without destruction of the incident pion. This is a background event NOT a signal event.

Defining Charge Exchange

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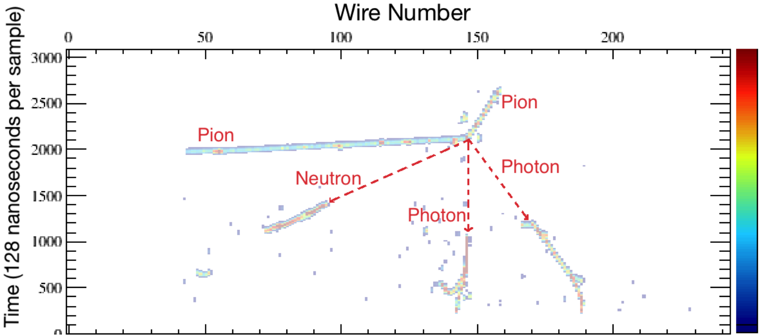

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What is a cross section?

- The cross section σ(E) is an energy dependent function describing the probability of a particle interaction as its area

Generic Cross Section Calculations

$$P_{Survival} = e^{-\sigma nz} \tag{1}$$

$$P_{Interacting} = 1 - P_{Survival} \tag{2}$$

$$\frac{N_{Interacting}}{N_{Incident}} = P_{Interacting} = 1 - e^{\sigma nz} \tag{3}$$

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Via a Taylor expansion...

$$P_{Interacting} = 1 - (1 - \sigma nz + ...) \tag{4}$$

$$\sigma(E) \approx \frac{1}{nz} \frac{N_{Interacting}}{N_{Incident}} \tag{5}$$

Finding n for our Liquid Argon Slabs

n is the number density of the target particle, in our case nucleons.

$$n = \frac{\rho N_A}{A} \tag{6}$$

Where ρ is the density of liquid Argon, N_A is Avogadro's number, and A is the atomic weight of Argon.

$$n = \frac{1.4\ grams}{cm^3} \frac{mol}{40\ grams} \frac{6.022 * 10^{23}\ nucleons}{mol} \tag{7}$$

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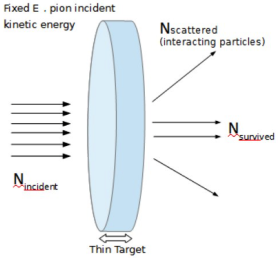
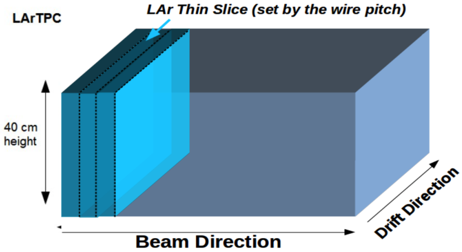
Given a slab thickness (z) of 1 cm,

$$\sigma(E) = \frac{N_{Interacting}(E)}{N_{Incident}(E)} \frac{1}{nz} = \frac{N_{Interacting}(E)}{N_{Incident}(E)} * 47.44 \frac{barns}{nucleon} \tag{8}$$

Thin Slab Method





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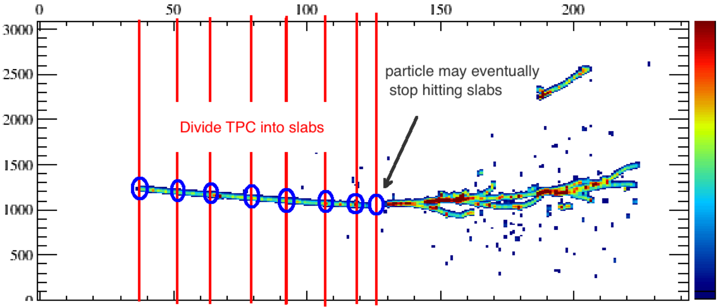


If the primary particle track (simulated π^- shown) has not ended, fill a histogram at the particle's energy for incident particles.
If the primary particle track has ended, fill a histogram at the particle's energy for interacting particles.
This particle would have passed through about 50 slabs

Monte Carlo Cross Section

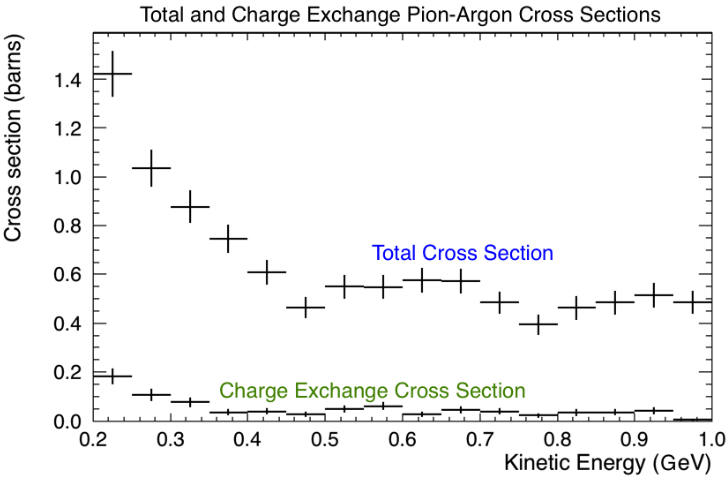


Figure: Monte Carlo measurements of total and CEX cross sections calculated via the thin slab technique

Pion-Proton Discrimination

Energy Deposition Distributions

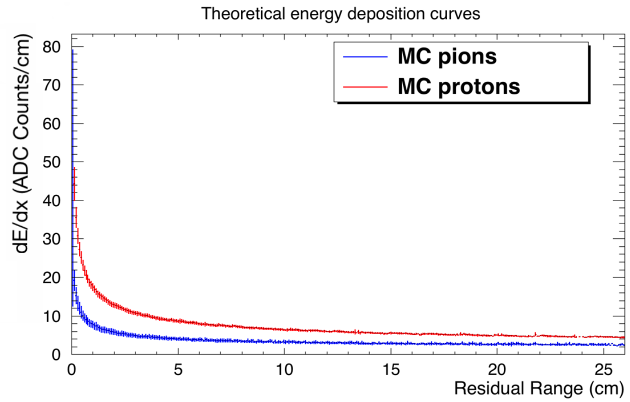
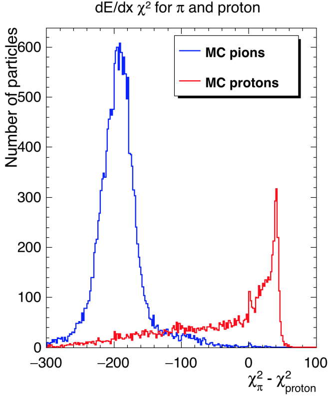


Figure: Theoretical Energy deposition for pions and protons. Used to create a χ^2 value for both the proton and pion hypothesis

Pion-Proton Discrimination
$\Delta\chi^2$ separation



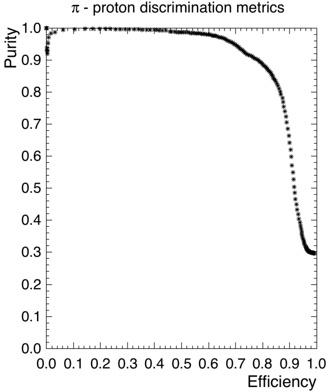


Figure: Depending on the placement of the threshold for being classified as a proton or pion we will get a purity and efficiency at one of the points in the plot on the right

Future Work

Now that events are selected in which the incident pion was mutated in some way in the interaction and did not simply scatter we must verify that the interaction was charge exchange.

Future work will include:

- Verifying the effectiveness of current shower finding algorithms
- Using reconstructed electromagnetic shower objects to reconstruct the invariant mass of the π^0
- Making a charge exchange cross section measurement on real data